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Naomi Colton
University of Arkansas, Fayetteville

Kristofor Brye
University of Arkansas, Fayetteville

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Naomi C. Colton and Kristofor R. Brye§*

ABSTRACT

Tillage can negatively affect soil physical properties such as bulk density, organic matter content, and soil hydraulic properties, which in turn affect how plants grow. The objective of this study was to evaluate water retention characteristics of a Jay silt loam soil under cultivated agriculture and native tallgrass prairie in northwest Arkansas. Air-dry soil samples collected from 0-10 cm depth were re-wet with varying amounts of distilled water to create a range of water contents. After overnight equilibration, the water potential was measured on the re-wet soil samples using a dewpoint potentiameter. The relationship between water potential (Ψ) and water content (θv) for the cultivated agricultural and undisturbed prairie soil was modeled using the equation $\Psi = a\theta v^{-b}$, where a and b are coefficients determined from fitting the data and represent the water retention characteristics for the soil of the two different land uses. The a and b coefficients did not differ significantly due to land use. Therefore, the results of this study did not support our hypothesis that agricultural land use significantly affects water retention characteristics. However, increasing the number of soil samples in which the water potential was measured could have sufficiently decreased the variability in the a and b coefficients so that significant differences in water retention characteristics as a result of land use could have been demonstrated.

* Naomi Colton is a senior majoring in environmental, soil, and water science.

§ Kristofor Brye, faculty sponsor, is an assistant professor in the Department of Crop, Soil, and Environmental Sciences .

INTRODUCTION

Disturbing the soil with tillage can alter soil physical properties. Tillage influences the soil organic matter content and the soil's ability to retain and supply water to plants. Organic matter helps hold sand, silt, and clay particles together to form soil aggregates, which promote good soil structure. Organic matter also increases the soil's capacity to hold water. Consequently structure and organic matter, which are both influenced by tillage, affect water retention in soil.

Tillage also affects soil bulk density. Bulk density is the mass of dry soil per unit volume, which consists of both solids and void space (i.e., pores). Soil with a large volume of void space compared to the volume of solids has a lower bulk density, whereas a typical bulk density for well-structured soil is 1.3 Mg/m^3.

A soil with good structure has both macro- and micropores. Macropores allow water to readily infiltrate the soil. Micropores retain the water so that it doesn't flow through the soil profile too quickly; consequently the water is held for plants to extract. Undisturbed soils that are well structured, such as prairie soils, typically have a greater volume of pore space than cultivated soils because cultivation has disturbed the natural structure and in some cases caused soil compaction.

Prairie soils that have not been affected by agricultural practices also typically have higher organic matter content than cultivated soils. Since prairie soils are high in organic matter, they also tend to have better structure and water retention characteristics than cultivated soils. In a study conducted by Scott et al. (1983), virgin Dubbs and Sharkey soils from eastern Arkansas were compared to soil of the same series that had been cultivated. Results showed that the virgin soils contained higher amounts of organic matter and retained more water, but had lower bulk densities than the cultivated soils (Scott et al., 1983).

The objective of this study was to compare water retention characteristics of a cultivated and undisturbed Jay silt loam soil in northwest Arkansas. We hypothesized that, similar to the findings in eastern Arkansas, land use significantly affects water retention characteristics.

MATERIALS AND METHODS

Site Description

The study site was located on a 24.3-ha tract of land in Benton County, Arkansas, approximately 4.8 km north of Siloam Springs. This tract of land, known as the Chesney Prairie, was acquired by the Arkansas Natural

MEET THE STUDENT-AUTHOR

Naomi Colton

I am from Rogers, Ark., where I graduated from Rogers High School. I am a senior majoring in environmental, soil and water science in the Department of Crop, Soil, and Environmental Sciences.

During Summer 2001, I began working for Dr. Brye and got involved in some of his work relating to soil physics and soil-quality assessments of disturbed (i.e., cultivated agriculture) and undisturbed (i.e., native prairie) soils. He took some of the work I was doing and turned it into a research project for me related to land use and water-retention characteristics. This opportunity has given me experience in knowing what goes into conducting a scientific experiment and how to write a scientific paper. The experience will be valuable for me no matter what I do.

I was an Earth Team volunteer during Spring 2002 for the Natural Resource Conservation Service (NRCS) in Washington County, AR. During Summer 2002, I was a student trainee with the NRCS, where I helped conduct and learned what goes into preparing a soil survey.

My future after graduation is undecided at this time. However, I would like to either continue working for the NRCS or attend graduate school to pursue a Master's degree in environmental science.

Heritage Commission (ANHC) in 2000. According to the ANHC, the Chesney Prairie is one of very few prairie remnants in the Arkansas portion of the Springfield Plateau (ANHC, 2001). Within the Chesney Prairie Natural Area, a unique combination of undisturbed prairie and cultivated agricultural land use exists adjacent to each other on the same soil (Fig.1). These two land uses reside on a Jay silt loam soil (fine-silty, mixed, thermic, mollic fragiudalf), which typically exists on the broad uplands of northwest Arkansas and is moderately well drained (Phillips and Harper, 1977).

The topography of the study area is gently rolling with the slope ranging from 1 to 2%. Prairie vegetation at the site includes native grasses such as big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), prairie cordgrass (*Spartina pectinata*), gayfeather (*Liatris pycnostachya*), and numerous other forbs and perennials (ANHC, 2001). The texture of the soil surface is silt loam and the upper part of the subsoil is silty clay loam. The Jay soil series is typically used for pasture and meadow in Northwest Arkansas. However, the cultivated portion of the Chesney Prairie had been typically planted to soybeans (*Glycine max*) in the past (ANHC, 2001). Cultivation was ceased at the site in 2000.

Field Sampling

A 60-m transect was established in the prairie and cultivated agricultural field. Two soil cores, 4.7 cm in diameter, were collected using a slide hammer from the 0 to12 cm depth at five points spaced 15 m apart along the transects. The samples were used for bulk density determination, particle-size analysis, and determination of water retention characteristics.

Laboratory Procedures

One of the two soil cores collected at each of the five points along the transects was air dried for 48 hrs, ground, and sieved through a 2-mm mesh screen. Three of five air-dried soil samples were used to determine water retention characteristics. Nine 5 ± 0.1 gram samples of air-dried soil were weighed out into small cups. Varying amounts of distilled water (i.e., 2, 4, 6, 10, 12, 15, 20, 30, and 40 drops) were added to the cups and the wet soil was mixed thoroughly. The cups were covered and allowed to equilibrate overnight. The following day the water potential of the soil in each cup was measured with a dewpoint potentiameter (Model WP4, Decagon Devices, Inc., Pullman, Wash.). The dewpoint potentiameter measures the water vapor pressure of the air in the sample chamber after the air in the sample chamber has equilibrated with the liquid water in the soil sample. After measuring the water potential, the gravimetric water content of the soil in each cup was determined by drying at 70°C for approximately 10 to 12 hrs.

The second of the two soil cores collected at each of the five points along the transects was weighed, oven dried at 70°C for 48 hrs, and reweighed for bulk density determination. Bulk density (ρb) was calculated by the following equation:

ρb= (mass of wet soil – mass of dry soil)/sample volume [1]

where the sample volume was 208 cm^3. Once oven dried, soil samples were ground and sieved through a 2-mm mesh screen. Particle-size analysis was determined on a 40-g subsample of oven-dry soil from each of the five points along the transect by a standard hydrometer method (Arshad et al., 1996).

Statistical Analysis

A one-way analysis of variance (ANOVA) was performed to determine the effect of land use on bulk density and the percentages of sand, silt, and clay (Minitab, 1997). Measured water potentials for each replicate soil sample (n = 3) were plotted against the corresponding volumetric water content, which was calculated by multiplying the gravimetric water content by the soil's bulk density. The equation $\Psi = a\theta v^{-b}$ was fit to the resulting curves using a spreadsheet, where Ψ is the water potential (-MPa); θv is the volumetric water content; and a and b are coefficients determined from fitting the data and represent water retention characteristics of the soil. An ANOVA was also performed to determine the effect of land use on water retention characteristics (i.e., the a and b parameters). Data are reported as mean values with statistical significance among means determined by $P < 0.05$.

RESULTS AND DISCUSSION

Particle-Size Analysis

Mean percent of sand, silt, and clay were 21.8, 68.6, and 9.7% respectively (Table 1), in the undisturbed prairie. In the cultivated agricultural soil, mean percentages of sand, silt, and clay were 23.5, 67.0, and 9.5% respectively (Table 1). Particle-size analysis demonstrated that the percentages of sand, silt, and clay in the top of the undisturbed prairie and cultivated agricultural field did not differ significantly ($P<0.05$) (Table 1).

Therefore both soils do indeed have the same soil texture (i.e., silt loam), which is congruent with how the soil in the area was originally mapped. Since the textures are similar, this indicates that the soils being compared are relatively the same and the results hereafter will be a comparison of two like soils.

Bulk Density

Bulk density in the top 12 cm averaged 1.12 and 1.30 g/cm^3 in the native prairie and cultivated agricultural

A

B

Fig. 1. Native tallgrass prairie (A) and previously cultivated agricultural (B) land uses at the Chesney Prairie Natural Area near Siloam Springs in Benton County, Ark.

field, respectively (Table 1). The bulk density of the prairie soil was significantly lower (P<0.05) than that of the cultivated agricultural soil (Table 1). This difference indicates that the prairie soil has a greater volume of pore space than the cultivated soil. The greater volume of pore space in the prairie allows water to infiltrate through the soil and be retained more readily than in the cultivated soil. These results for disturbed and undisturbed soils in northwest Arkansas are similar to the finding of Scott et al. (1983) for a similar setting of adjacent disturbed and undisturbed soils in eastern Arkansas.

Water Retention Characteristics

The soil-water potential increased and leveled off as water content increased in the native prairie and cultivated agricultural soil (Fig. 2). However, water retention characteristics (i.e., the modeled a and b coefficient of the equation $\Psi = a\theta v^{-b}$), as determined using soil-wetting curves, did not differ significantly by land use (Table 2). The a coefficient did not differ significantly (P<0.05) among land uses. Similarly, the b coefficient did not differ significantly (P<0.05) among land uses. Therefore, the results of this study, acquired using soil-wetting curves, did not support the hypothesis that land use significantly affects water retention characteristics.

Several reasons may exist to explain these results. Along each transect, five soil samples were collected. However, only three of the five soil samples collected were used to determine water retention characteristics. Had all five soil samples been used to determine water retention characteristics, the variability associated with the mean values of the a and b coefficients would most likely have decreased, which may have resulted in significant differences among mean values for the a and b coefficients. In addition, the hypothesis that land use affects water retention characteristics was based on results from Scott et al. (1983), in which water retention characteristics were determined using soil-drying curves rather than soil-wetting curves, which were used in this experiment.

In the Scott et al. (1983) study, after obtaining an intact soil core, the soil was saturated, placed in a chamber, and pressurized at various levels to dry the soil core. The intact soil core was neither air dried nor ground and sieved. Therefore, the original structure was left undisturbed. In contrast, the soil samples collected in this study were air dried, ground, and sieved. Altering the original structure of the soil by air drying, grinding, and sieving affected the outcome of this study so that we were unable to demonstrate significant differences in water retention characteristics due to land use.

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Table 1. Summary of the effects of land use (i.e., undisturbed prairie versus cultivated agriculture) on soil particle size and bulk density.

Land use	n	Sand	Silt	Clay	Bulk density
			%		g/cm^3
Cultivated agriculture	5	23.5a^z	67.0a	9.5a	1.30a
Native prairie	5	21.8a	68.6a	9.7a	1.12b

^{z} Different letters after mean values represent significant differences (P< 0.05).

Table 2. Summary of the effects of land use (i.e., undisturbed prairie versus cultivated agriculture) on mean water retention characteristics (i.e., the a and b parameters of the model $\Psi = a\theta v^{-b}$).

Land use	n	a coefficient	b coefficient
Cultivated agriculture	3	0.081a^z	1.43a
Undisturbed prairie	3	0.096a	1.23a

^{z} Different letters after mean values represent significant differences (P< 0.05)

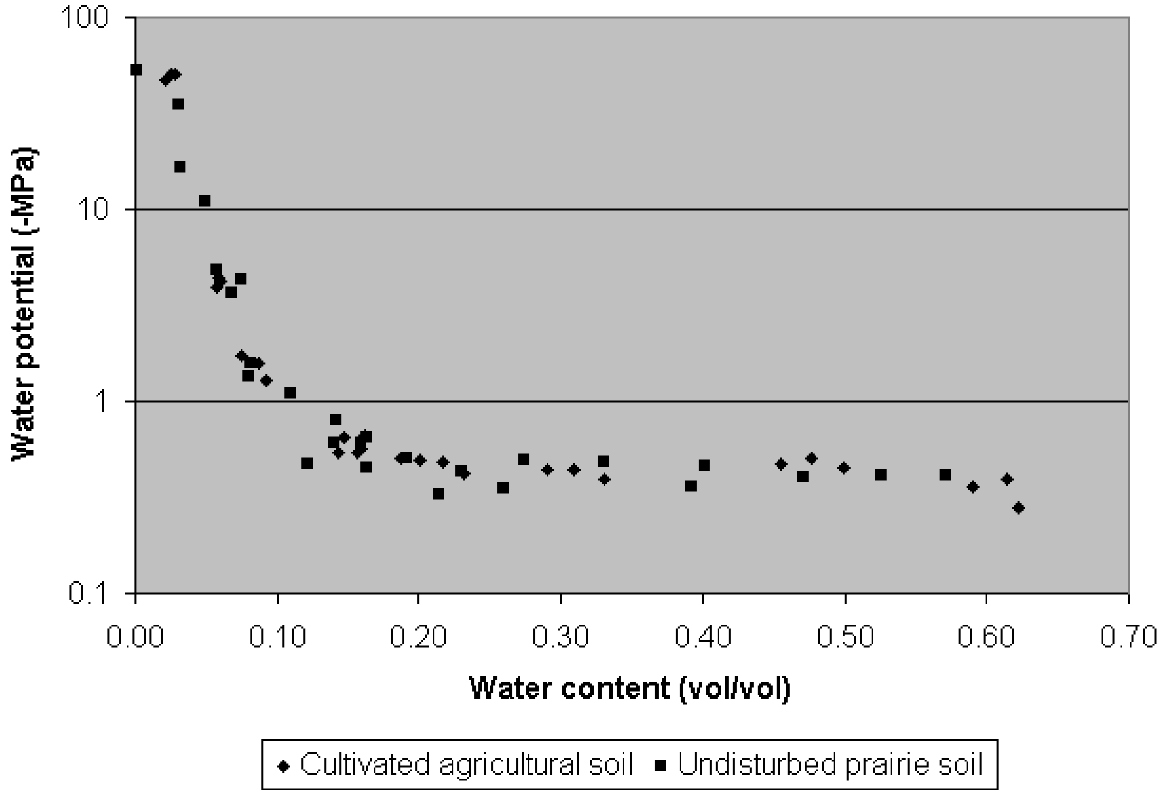

Fig. 2. The relationship between water potential, plotted on a log scale, and volumetric water content for a cultivated and undisturbed Jay silt loam soil in northwest Arkansas.